

6C07:

**Using Radio-Frequency Electrical Measurements
as a Plasma Diagnostic**

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Radio frequency (rf) current and voltage measurements are an important and convenient tool for monitoring rf discharges. These measurements are compatible with commercial reactors and with the manufacturing environment. Recently, methods have been proposed for using rf electrical measurements to monitor process-relevant plasma properties. These methods rely on models that relate measured electrical parameters to physical properties such as the densities, fluxes, and energies of electrons and ions. Unfortunately, the models that are used often rely on untested assumptions. In particular, the sheath regions of the plasma are difficult to model without the aid of simplifying assumptions. To test these assumptions and to provide a firmer foundation for rf-based diagnostics, electrical studies were performed in high-density discharges in an inductively coupled GEC Reference Cell, at pressures of 0.67-4.0 Pa, inductive source powers up to 370 W, rf bias powers up to 150 W, and rf bias frequencies of 0.1-13.56 MHz. External measurements of current and voltage waveforms were combined with capacitive probe measurements of the rf plasma potential and independent measurements of ion current and ion energy. Together, these measurements provide enough information to test electrical diagnostic techniques and the models that these techniques are based on. Here, a comprehensive test and comparison of methods for determining the ion flux in argon and CF_4 discharges will be presented. Methods which use high-frequency or low-frequency approximations to ion motion were found to be less accurate than methods based on a new, complete model of the time-dependent ion dynamics in the plasma sheath. Methods for obtaining ion energies from rf measurements will also be presented.

6C08:

**Real-Time Feedback Control of Ion Energy Flux in Chlorine
Inductively Coupled Plasma for Poly-silicon Etch Process**

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The advanced semiconductor fabrication requires more tighten process monitoring and control to improve production yield and reliability. Recently, advanced process control (APC), an *in-situ* sensor based methodology, has been applied to achieve the desired process goals in operating individual process steps [1]. For instance, in etching of polysilicon using chlorine discharges, in order to obtain a desired etch profiles, the process often is operated at the ion-enhanced regime where the etch rate and etched profile are strongly dependent on the total ion energy flux incident on the wafer surface. Therefore, a better process control can be achieved if one can implement the real-time control of ion energy flux in etch processing. In this study, we have demonstrated experimentally the real-time multiple-input multiple-output (MIMO) control of both ion density and ion energy in etching of polysilicon using chlorine inductively coupled plasma. To measure relative positive ion density, the optical emission at 750.4 nm from trace amounts of Ar is used which is proportional to the total positive ion density [2]. An rf voltage meter is adopted to measure the peak rf voltage on the electrostatic chuck which is linearly dependent on sheath voltage [3]. One actuator is a 13.56 MHz rf generator having a maximum power of 5 kW to drive the inductive coil seated on a ceramic window, along with a L-type matching network to minimize the reflected power. The second actuator is also a 13.56 MHz rf generator to power the electrostatic chuck via a matching network. The two rf generator is locked in phase. The design of MIMO controller is applied by *Quantitative Feedback Theory (QFT)* to compensate process drift, process disturbance, and pilot wafer effect. The experiment results showed that the MIMO control system has a better reproducibility in etch rate as compared to current industrial practice.

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- [3] R. Patrick, S. Baldwin and N. Williams, *J. Vac. Sci. Technol. A*, **18**, 405-410, 2000.